GE Global Research

Microturbine Developments at GE

Advanced Integrated Microturbine System

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Outline

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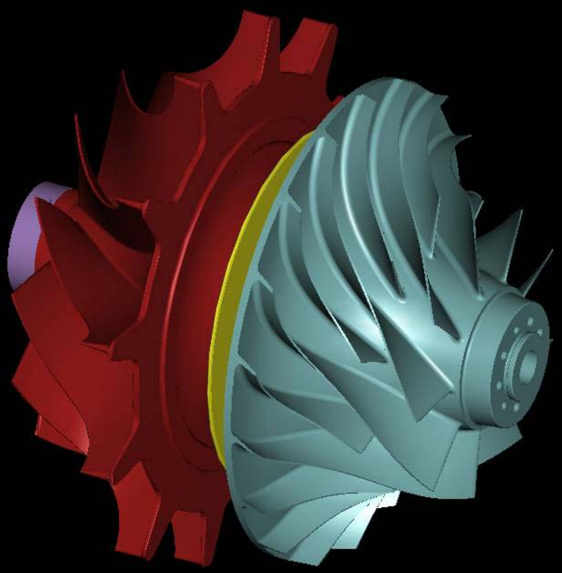
- **Summary**



Overview

OBJECTIVE

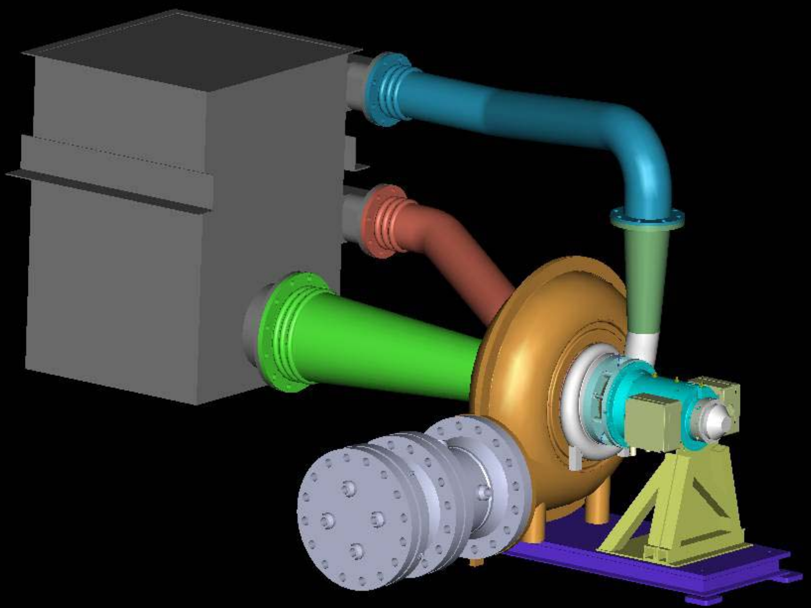
The objective of the AIMS program is to develop the next generation microturbine system that will advance the current generation system into a more efficient, cost effective, and environmentally friendly system. The resulting system will be designed such that it addresses both the current and emerging distributed generation markets.

PROJECT TEAM

GE Global Research
GE Power Systems (GEPS)
GE Industrial Systems (GEIS)
Concepts NREC
Turbo Genset Company
Kyocera Industrial Ceramics Corp.
Onsite Energy Corporation
Oak Ridge National Laboratory

CTQ'S

- 40% Efficient Design
- 175 kW Output with growth to +250 kW
- $\leq$ 10 ppm NOx on Natural Gas
- $\leq$ 10 ppm CO on Natural Gas
- $\leq$ \$500/kW unit cost
- 11,000 hour maintenance interval
- 45,000 hour life



Program Team

AIMS Program

Subtask A
Market Study

Onsite Energy/ GEPS
- Market Study

Task 1
Technology Concepts

GEGR
- Thermal analysis of cycle
- Advanced technology screening

GEGR/PSEC/GEIS
- Control system definition

Task 4
Laboratory Evaluation

GEGR
- Integration of developed components into the new system
- Evaluation of the system in a laboratory environment

Task 5
Commercial Demonstration

GEGR/ GEPS/ Site TBD
- 4000 hour demonstration of developed microturbine system

Task 2
Component Development

GEGR/ Concepts NREC/ GEPS
- Component development & testing

GE Research/ Kyocera/ ORNL
- Advanced material components
- Advanced material characterization
- Ceramic testing for database

GEGR/ GEIS/ TurboGenset
- Power electronics development
- High speed alternator development

Task 3
Systems Design

GEGR/ GEPS
- System integration issues
- Acoustic considerations

GEGR/ GEIS/ GEPS
- Control system development

Subtask B
Business Plan

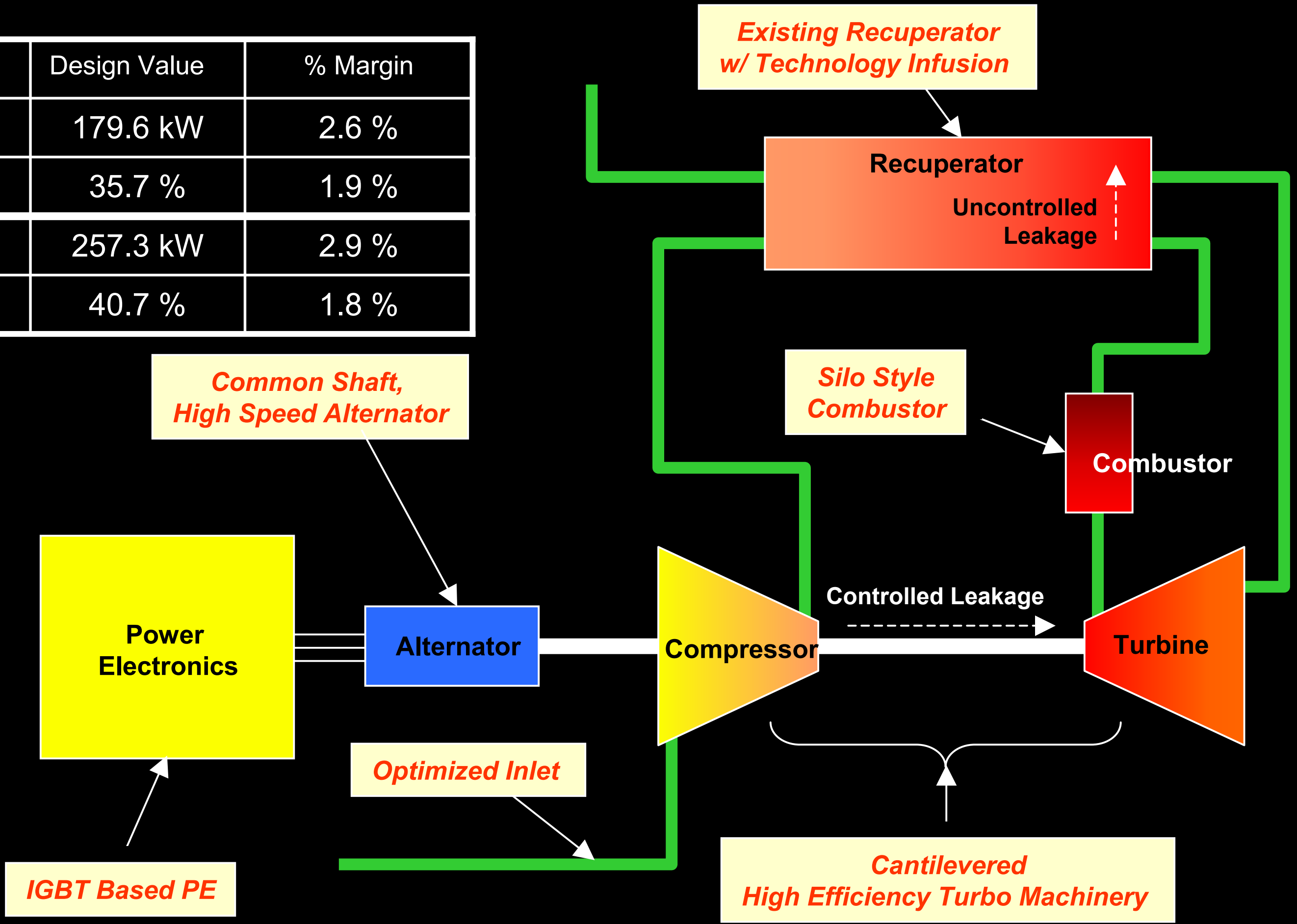
GEPS
- Business plan based on market analysis, product feasibility and technology maturity

Conceptual Design

TASK FOCUS:

- Determine system thermal design to achieve the 40% efficiency target
- Reduce the operating temperature of the cycle to "metallic" levels
  - *this process allows for proof of component technologies prior to the introduction of advanced materials*

	Target Value	Design Value	% Margin
Cycle Output	175 kW	179.6 kW	2.6 %
Cycle Efficiency	35 %	35.7 %	1.9 %
Cycle Output	250 kW	257.3 kW	2.9 %
Cycle Efficiency	40 %	40.7 %	1.8 %



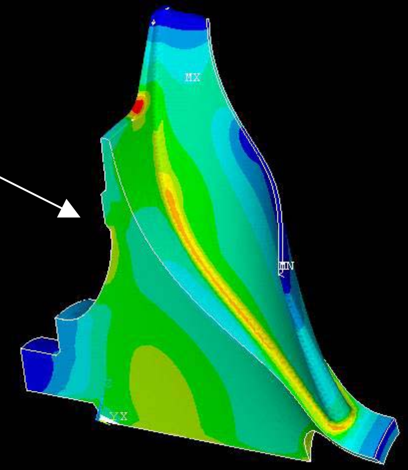
Turbomachinery

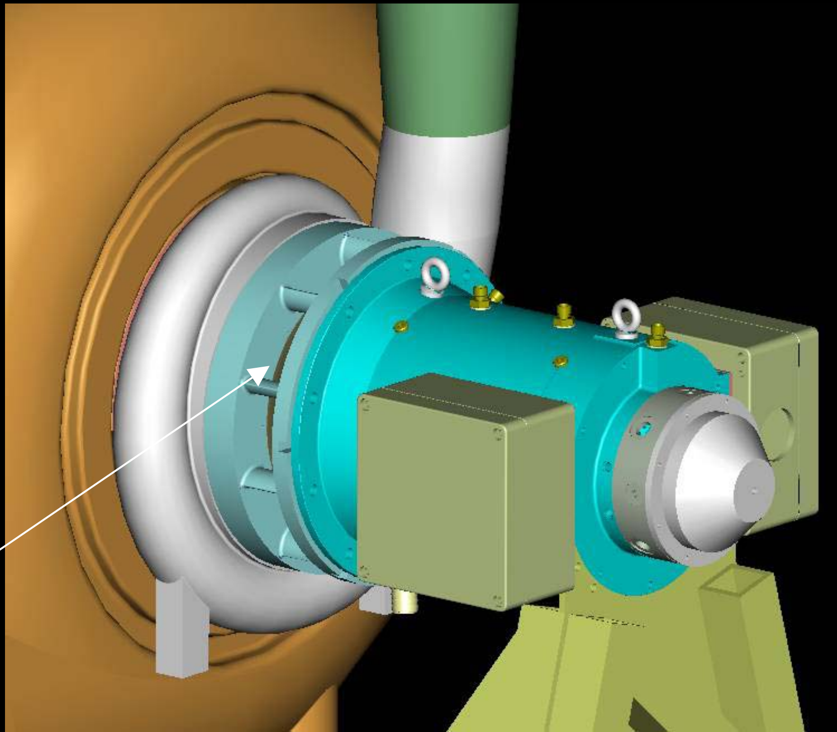
ACTIVITIES:

- Component Design Targets Set
- 1D Analysis (Flow & Stress)
- Rotor Dynamic Analysis
- Materials Down Selection
- 1st Pass 3D Analysis (Flow & Stress)
- Analysis of Results
- Modifications/ Redesigns
- Stationary Component Design & Analysis
- Final 3D Analysis (Flow & Stress)
- Final Rotor Dynamic Analysis

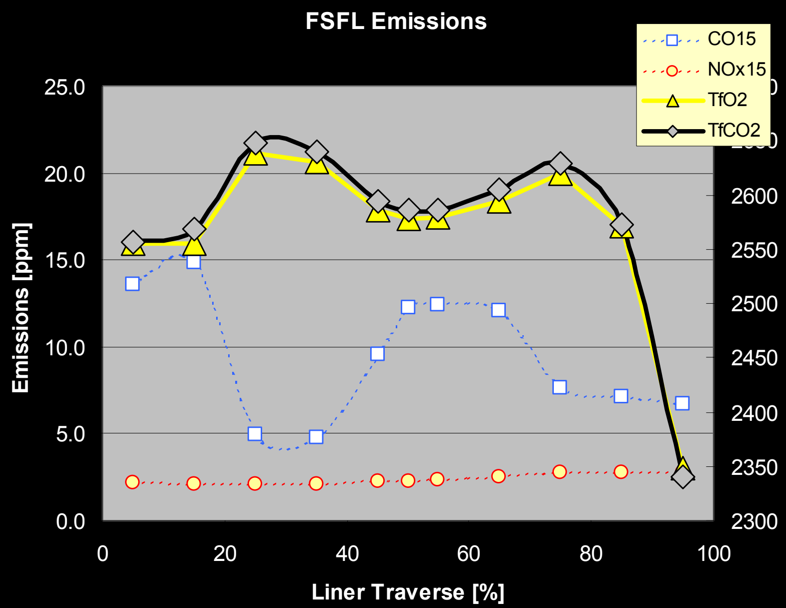
➡ Hardware Procurement

- Experimental Evaluation
- Integration with MT System
- Evaluation





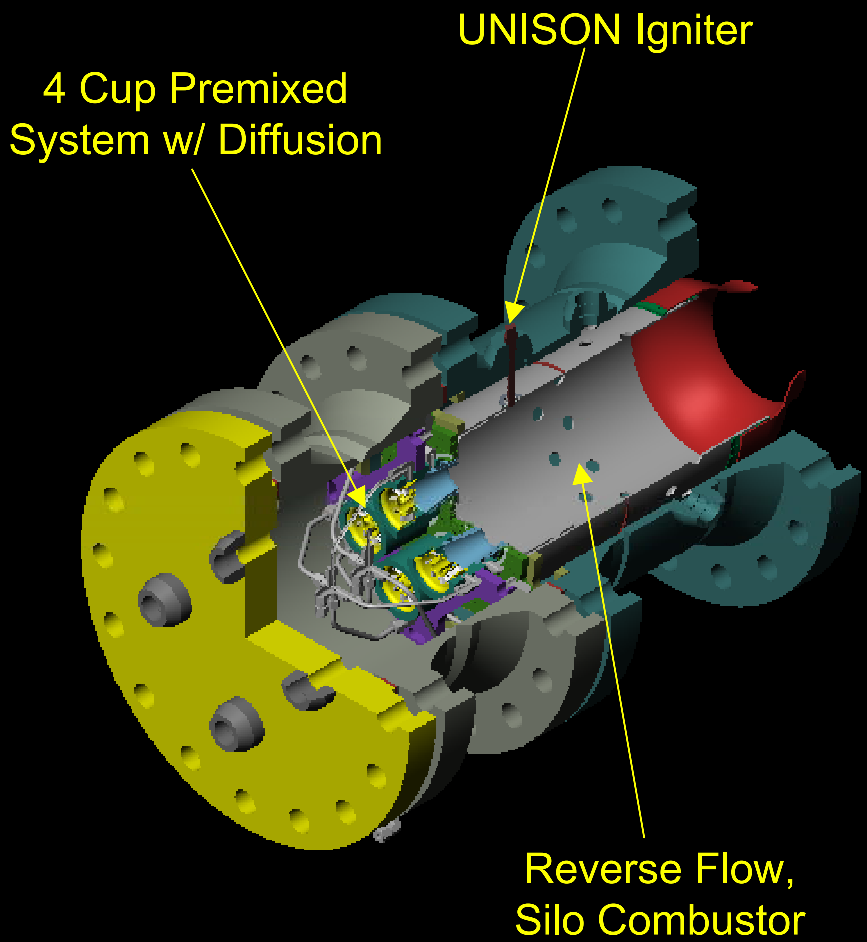
Combustion



Combustor Performance:

NOx (15% O_2) = 3.4 ppm

CO (15% O_2) = 8.4 ppm



Recuperator

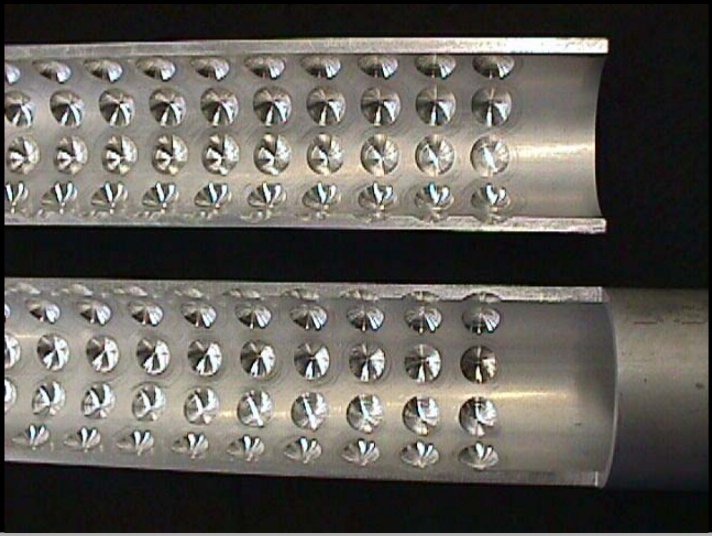
TASK FOCUS:

Infuse GE expertise of gas turbine heat transfer into existing recuperator technology to build a better system.

ACTIVITIES:

- Performance Design Targets Set
- Reverse Engineered Existing Recuperator – Validated with Experiments
- Preliminary Sizing of Recuperator
- Potential Heat Transfer Enhancement Technologies Identified
- Design Impact of Technologies Determined
- Capable Vendors Identified
- Vendor Finalized
- Initial Hardware Procurement
- New Technology Design Incorporation
- New Technology Sample Procurement
- New Technology Sample Experimental Evaluation
- New Technology Prototype Procurement
- Experimental Evaluation

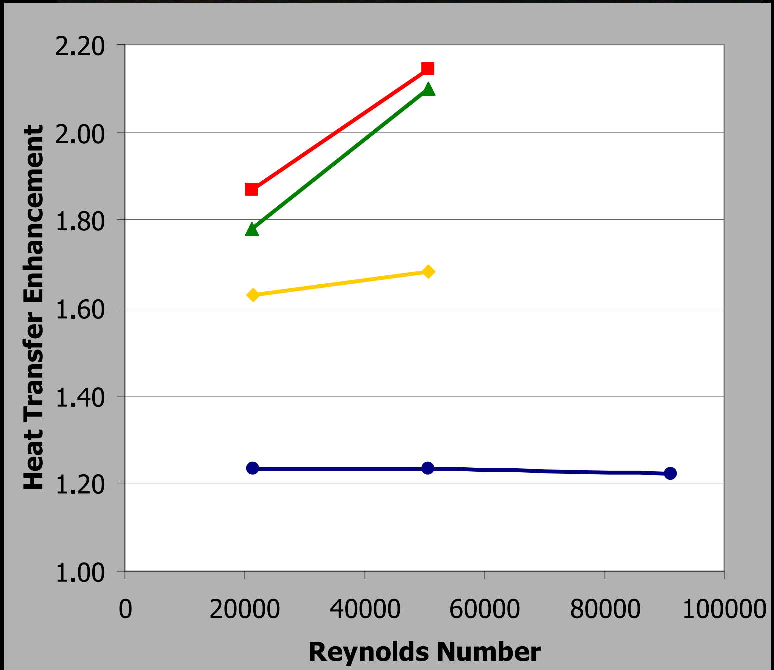
Recuperator

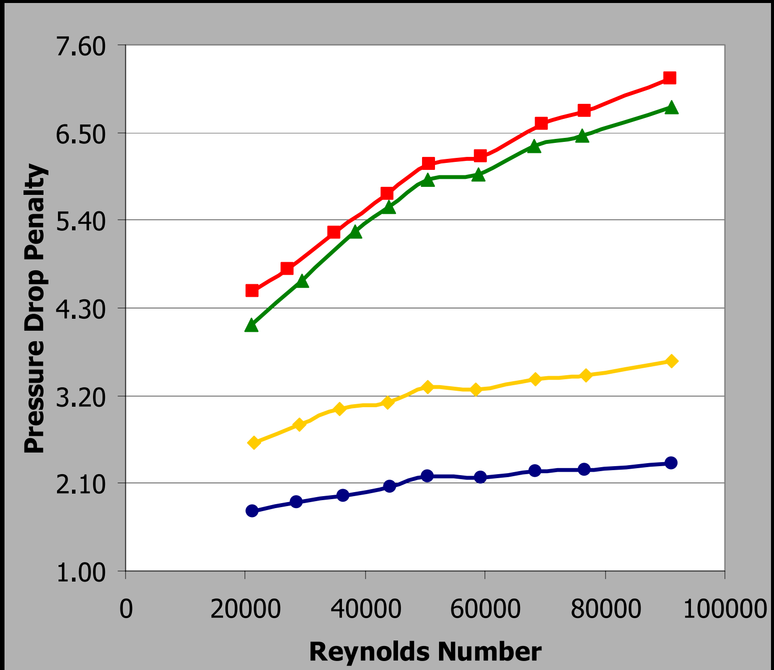


- Tube 1: Depth = 0.08", Spacing = 0.523"
- Tube 2: Depth = 0.16", Spacing = 0.4287"
- Tube 3: Depth = 0.16", Spacing = 0.523"
- Tube 4: Depth = 0.08", Spacing = 0.4287"

Dimple Diameter =0.39″

Tube Diameter = 1.50″

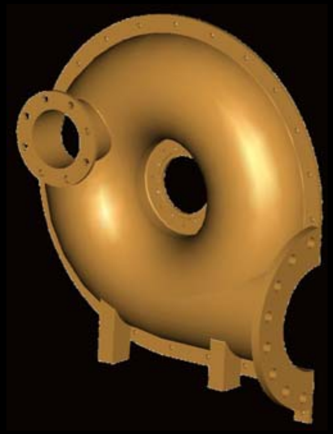


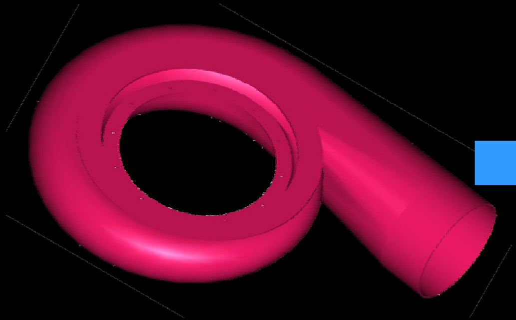


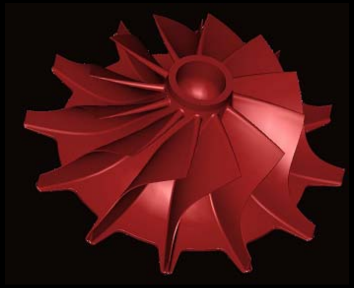
Core Engine Hardware Procurement

- Complete Digital Design
- Optimizations performed at the system level
- Design transferred as a 3D object for casting
- Held reviews with all parties present *(designer, casting vendor, machining vendor, welder, etc.)*
- As-cast SLA finish and dimensions better than expected

Digital







Castings

Core Engine Hardware Procurement

Core Engine Hardware Procurement

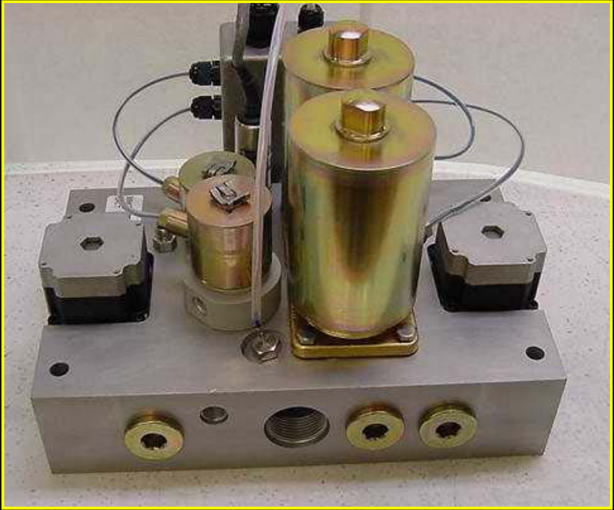
Control System

Hardware:

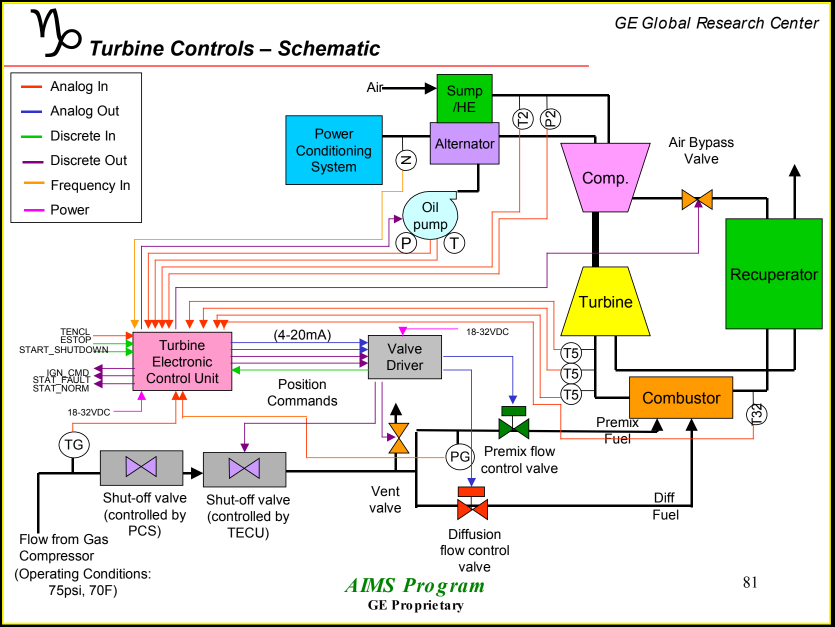
All hardware received and tested.

Testing:

- Completed:
  - Sensors and Actuators
  - Combustion Testing for Fuel Schedules
- Planned:
  Communication Test with Power Electronics



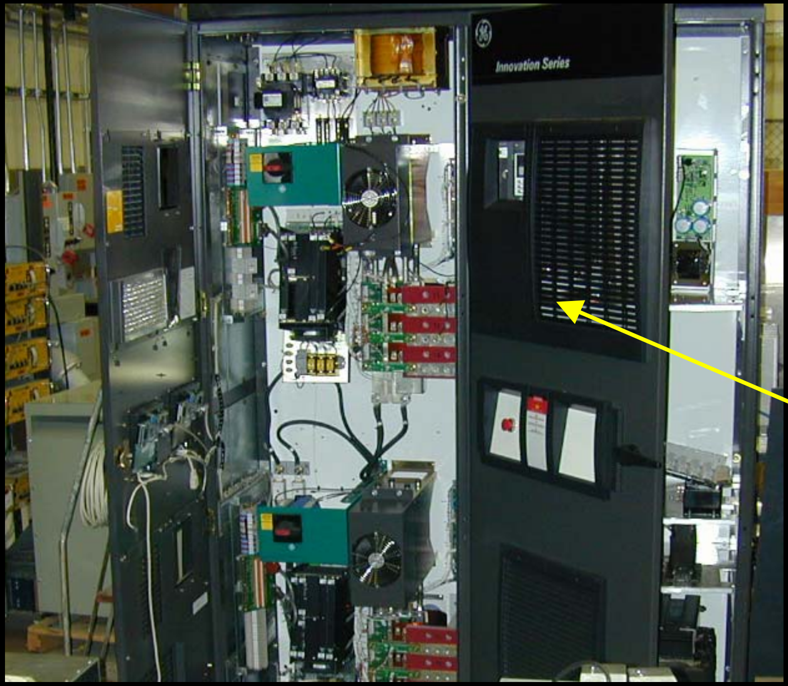
Woodward Valve Assembly



Power Electronics

PE ACTIVITIES:
- Specifications & Topology Tradeoffs
- Generator Vendor Selection
- Power Electronic Simulations
- Auxiliary System Design
- FMEA
- Component Fabrication
- System Tests
- Integration w/ Turbine System

CONTROLS ACTIVITIES:
- Control Requirements
- System Simulations
- Platform Selection
- Algorithm & Code Development
- Communication & HMI Development
- Hardware Procurement
- Integration w/ Turbine System



Summary

• Design, Build, and Test a 175 kW Microturbine with an electrical efficiency of ~35%. Show the path required to reach 40%

• Large, multidisciplinary team leveraging GE technology from *Industrial Systems*, *Aircraft Engines*, and *Power Systems*

• On-time procurement of hardware from vendors can be a challenge for proto-type machines

• On schedule to begin testing system late summer 2003